US009325945B2

(12) **United States Patent**
Saremi et al.

(10) **Patent No.: US 9,325,945 B2**
(45) **Date of Patent: Apr. 26, 2016**

(54) **VIDEO SERVER AND CLIENT WITH CUSTOM KEY EXCHANGE AND METHODS FOR USE THEREWITH**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 389 days.

(21) Appl. No.: **13/682,934**

(22) Filed: **Nov. 21, 2012**

(65) **Prior Publication Data**

US 2014/0140506 A1 May 22, 2014

(51) **Int. Cl.**

H04N 7/167	(2011.01)
H04N 21/2347	(2011.01)
H04N 21/262	(2011.01)
H04N 21/2662	(2011.01)
H04N 21/442	(2011.01)
H04N 21/6334	(2011.01)
H04N 21/658	(2011.01)
H04N 21/845	(2011.01)

(52) **U.S. Cl.**

CPC ***H04N 7/1675*** (2013.01); ***H04N 21/2347*** (2013.01); ***H04N 21/2662*** (2013.01); ***H04N 21/26258*** (2013.01); ***H04N 21/44209*** (2013.01); ***H04N 21/63345*** (2013.01); ***H04N 21/6582*** (2013.01); ***H04N 21/8456*** (2013.01)

(58) **Field of Classification Search**

CPC H04N 7/1675
USPC 726/28, 29, 30; 725/31, 116; 713/168, 713/189, 153; 709/219, 203, 231, 171; 380/44, 210, 255, 228, 212
See application file for complete search history.

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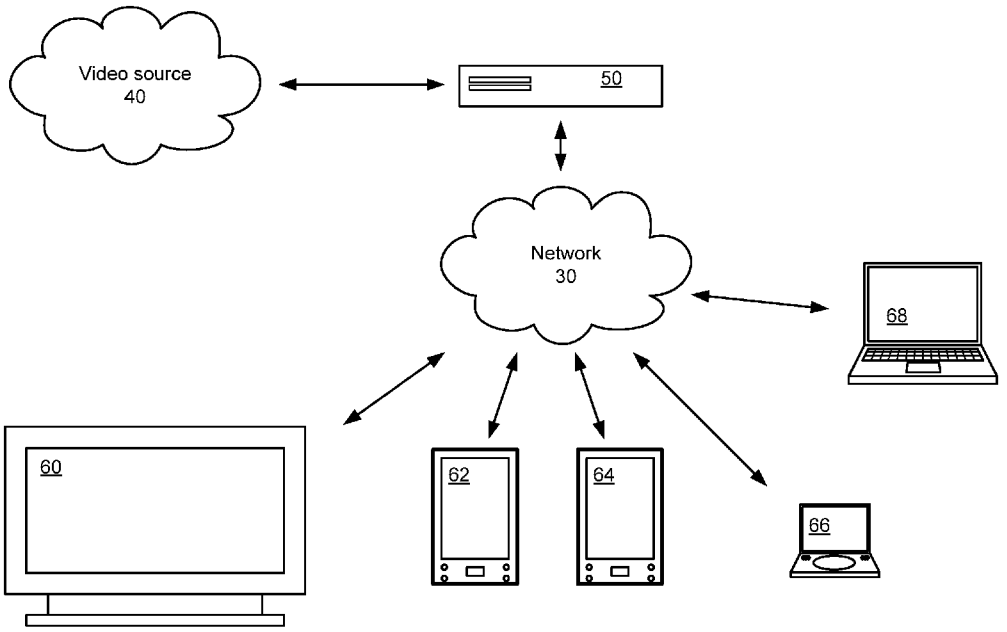
(57) **ABSTRACT**

A streaming video server stores playlist data corresponding to a plurality of video programs available from at least one video source. A command handler receives a program request for a selected one of the plurality of video programs from the at least one client device via the network interface and further receives a custom key request via a custom URI handler of the client device to access at least one encryption key. In response to the custom key request, the command handler sends secure key data to the client device in accordance with a custom key exchange protocol.

13 Claims, 11 Drawing Sheets



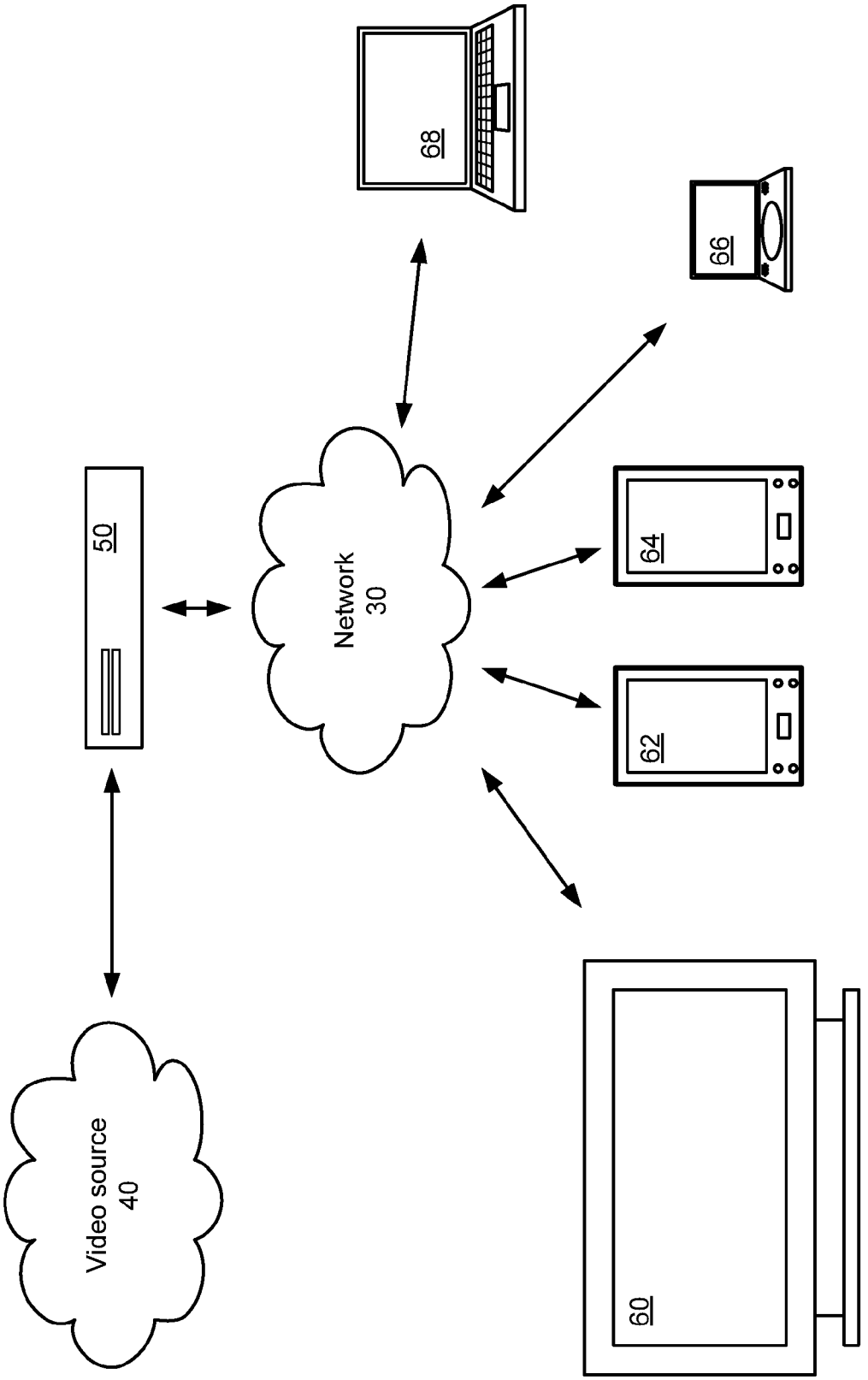


FIG. 1

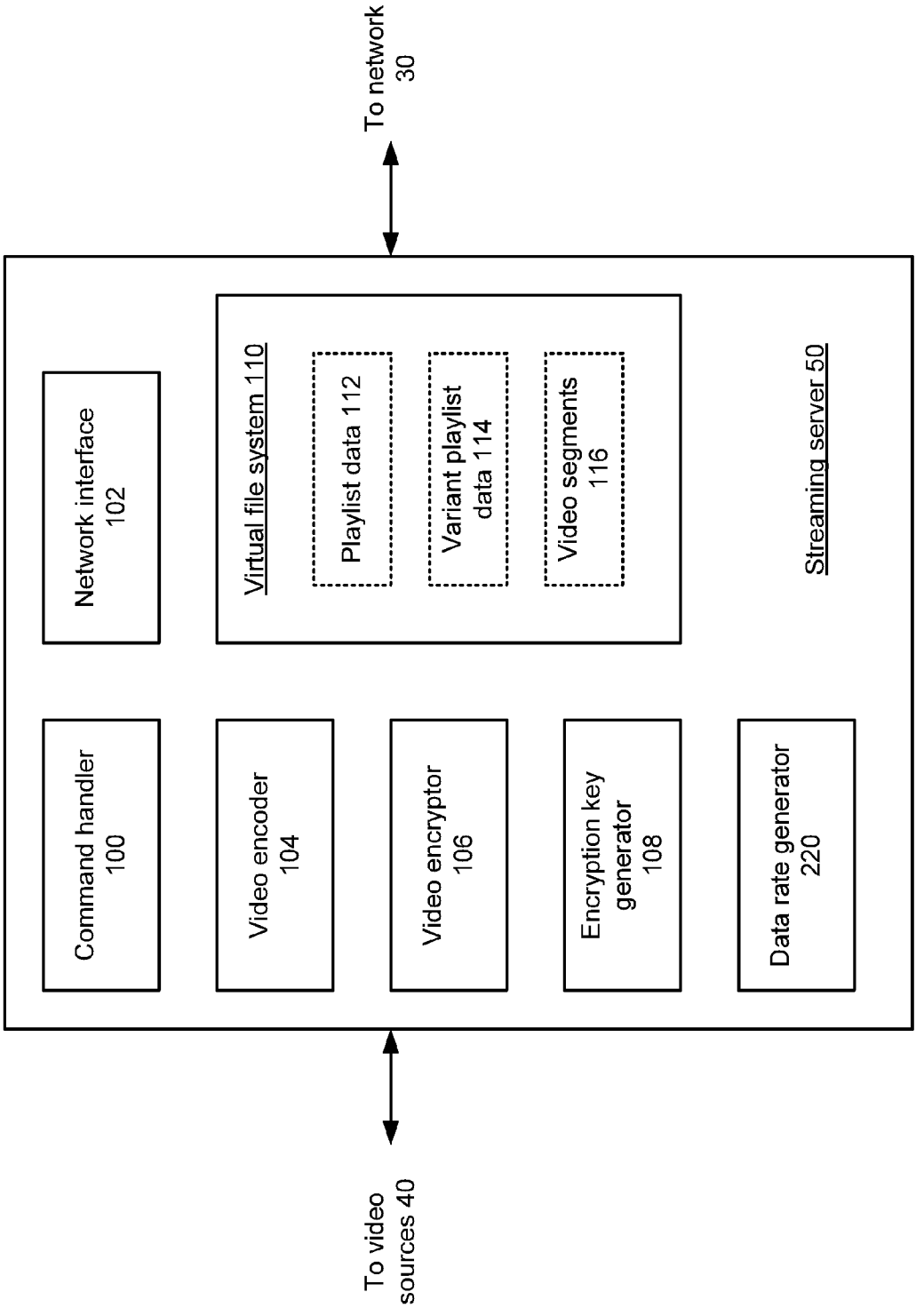

To network 30
Network interface 102
Virtual file system 110
Playlist data 112
Variant playlist data 114
Video segments 116
Streaming server 50
Command handler 100
Video encoder 104
Video encryptor 106
Encryption key generator 108
Data rate generator 220
To video sources 40

FIG. 2

Title	URL
Moon Wars	www.Morega.com/bwetyuyt
The Duchy Strikes Back	www.Morega.com/ashdkjhk
Return of the Antennae	www.Morega.com/qweiocbn
•	•
•	•
•	•

Content index 120

Playlist data 112

Title: Moon Wars

Segment#	Segment Address	Encryption Key URL
00000001	www.Morega.com/bwt00000001	www.Morega.com/bwt00000001ec
00000002	www.Morega.com/bwt00000002	www.Morega.com/bwt00000002ec
00000003	www.Morega.com/bwt00000003	www.Morega.com/bwt00000003ec
•	•	•
•	•	•
•	•	•

Segment playlist 122

FIG. 3


Variant playlist data 114
Title
Moon Wars
Bit Rate
256 kbps
Segment Playlist Address
www.Morega.com/256btw00000000

FIG. 4

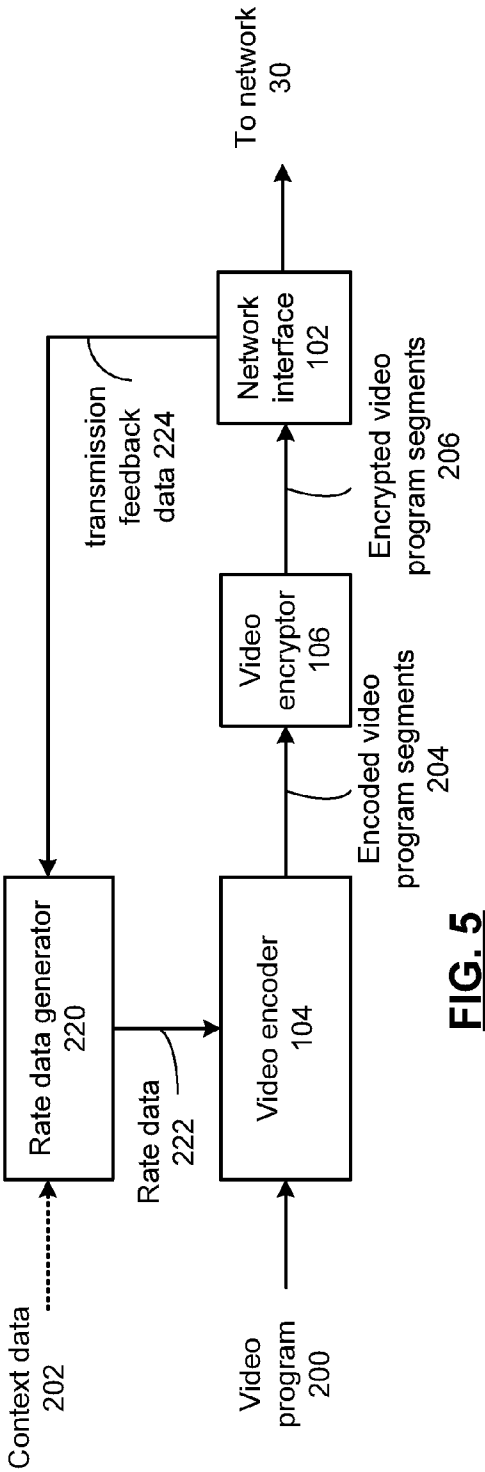

Context data 202
Video program 200
Rate data generator 220
Rate data 222
Video encoder 104
Encoded video program segments 204
Video encryptor 106
Encrypted video program segments 206
Network interface 102
transmission feedback data 224
To network 30

FIG. 5

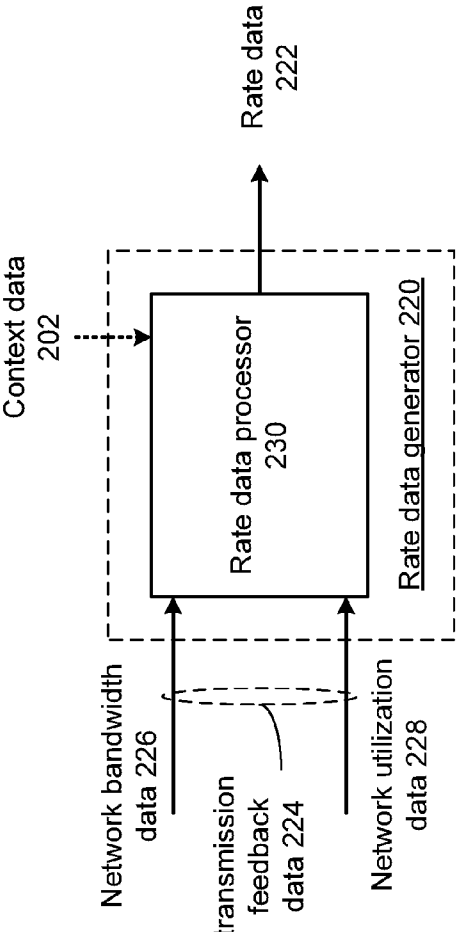

Context data 202
Rate data processor 230
Rate data 222
Rate data generator 220
Network bandwidth data 226
transmission feedback data 224
Network utilization data 228

FIG. 6

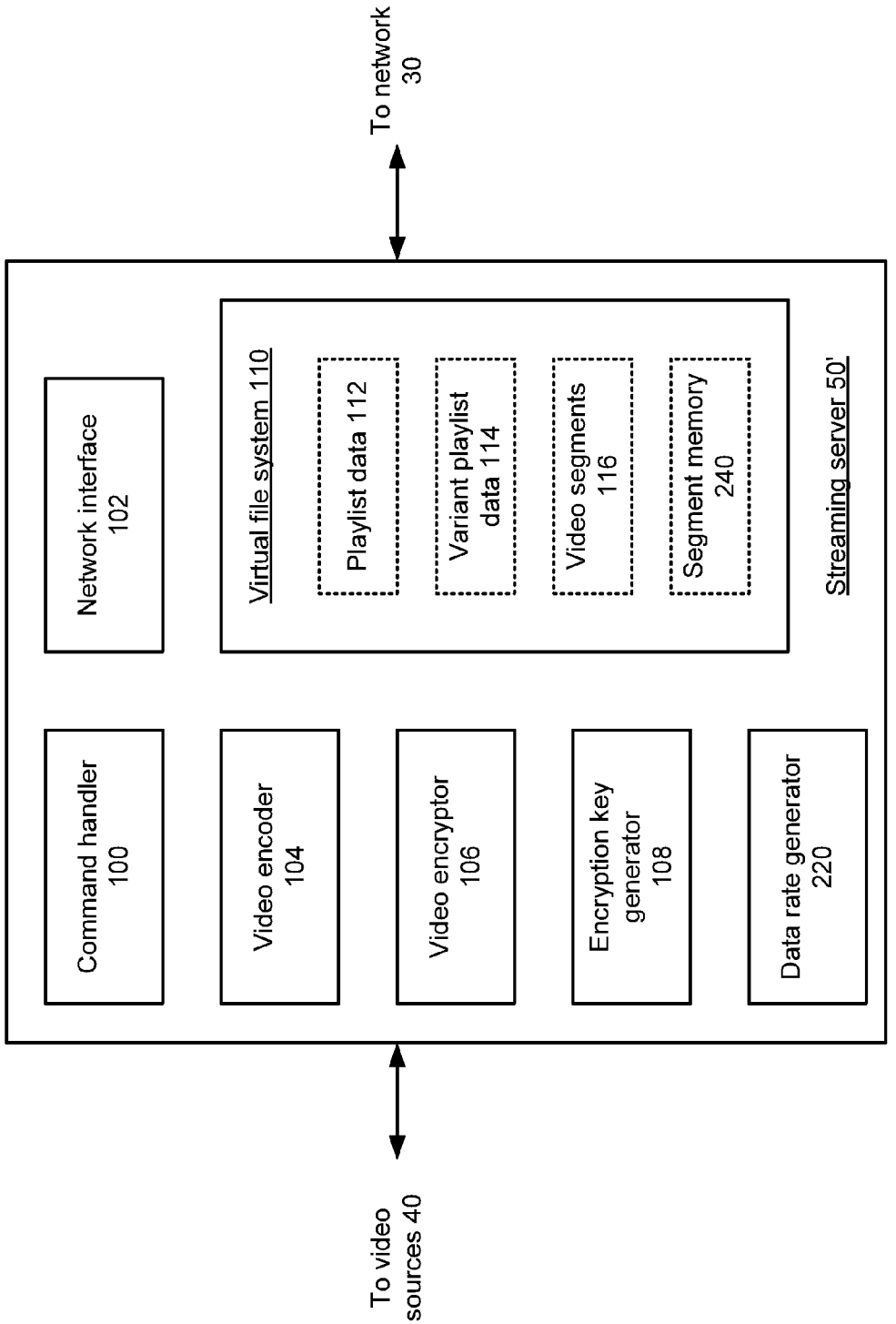

To network 30
Network interface 102
Virtual file system 110
Playlist data 112
Variant playlist data 114
Video segments 116
Segment memory 240
Streaming server 50'
Command handler 100
Video encoder 104
Video encryptor 106
Encryption key generator 108
Data rate generator 220
To video sources 40

FIG. 7

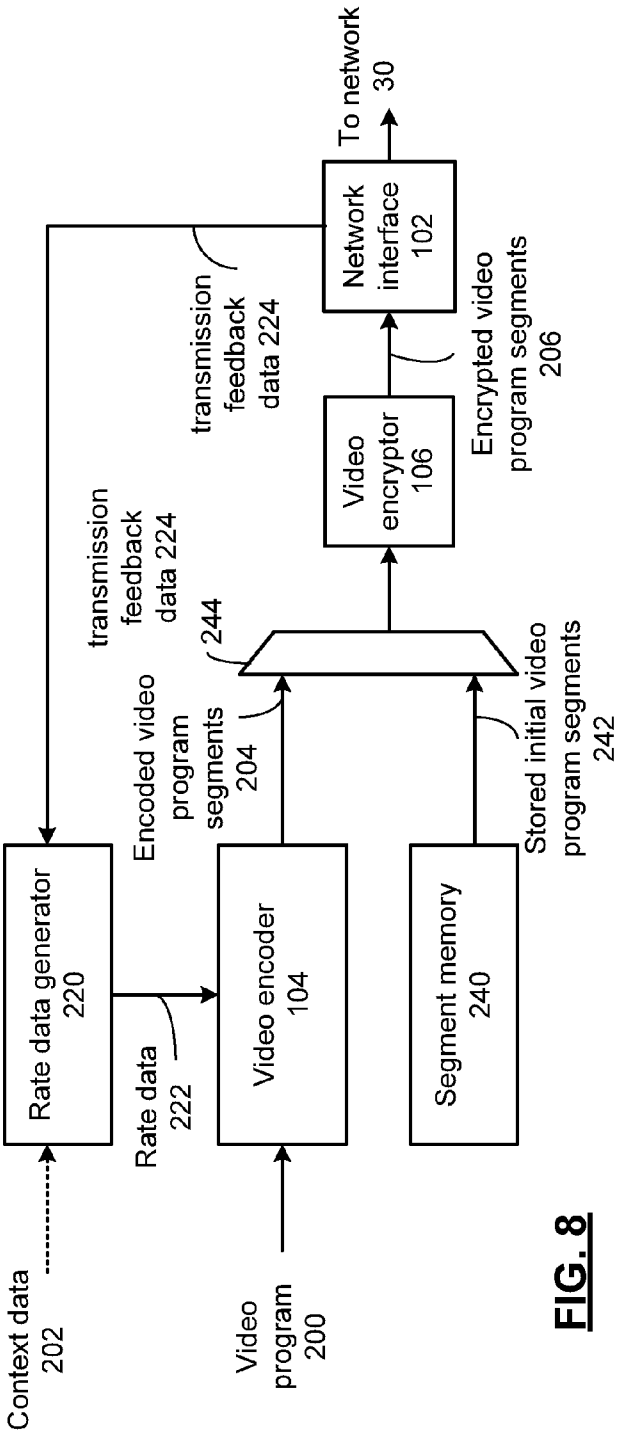

Context data 202
Video program 200
Rate data generator 220
Rate data 222
Video encoder 104
Segment memory 240
Encoded video program segments 204
Stored initial video program segments 242
244
transmission feedback data 224
Video encryptor 106
Encrypted video program segments 206
Network interface 102
To network 30
transmission feedback data 224

FIG. 8

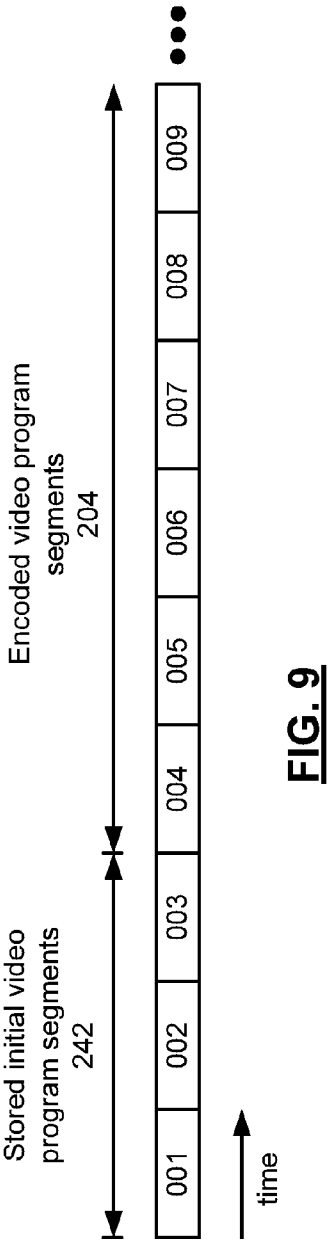

Encoded video program segments 204
Stored initial video program segments 242
001
002
003
004
005
006
007
008
009
time

FIG. 9

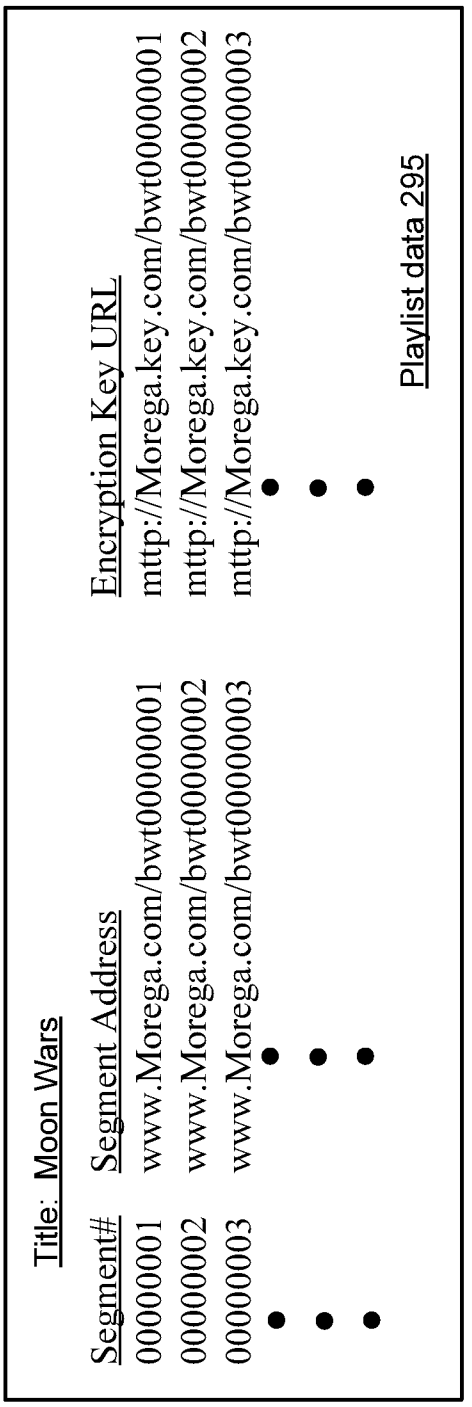

Title: Moon Wars
Segment#
Segment Address
Encryption Key URL
00000001
www.Morega.com/bwt00000001
mttp://Morega.key.com/bwt00000001
00000002
www.Morega.com/bwt00000002
mttp://Morega.key.com/bwt00000002
00000003
www.Morega.com/bwt00000003
mttp://Morega.key.com/bwt00000003
Playlist data 295

FIG. 10

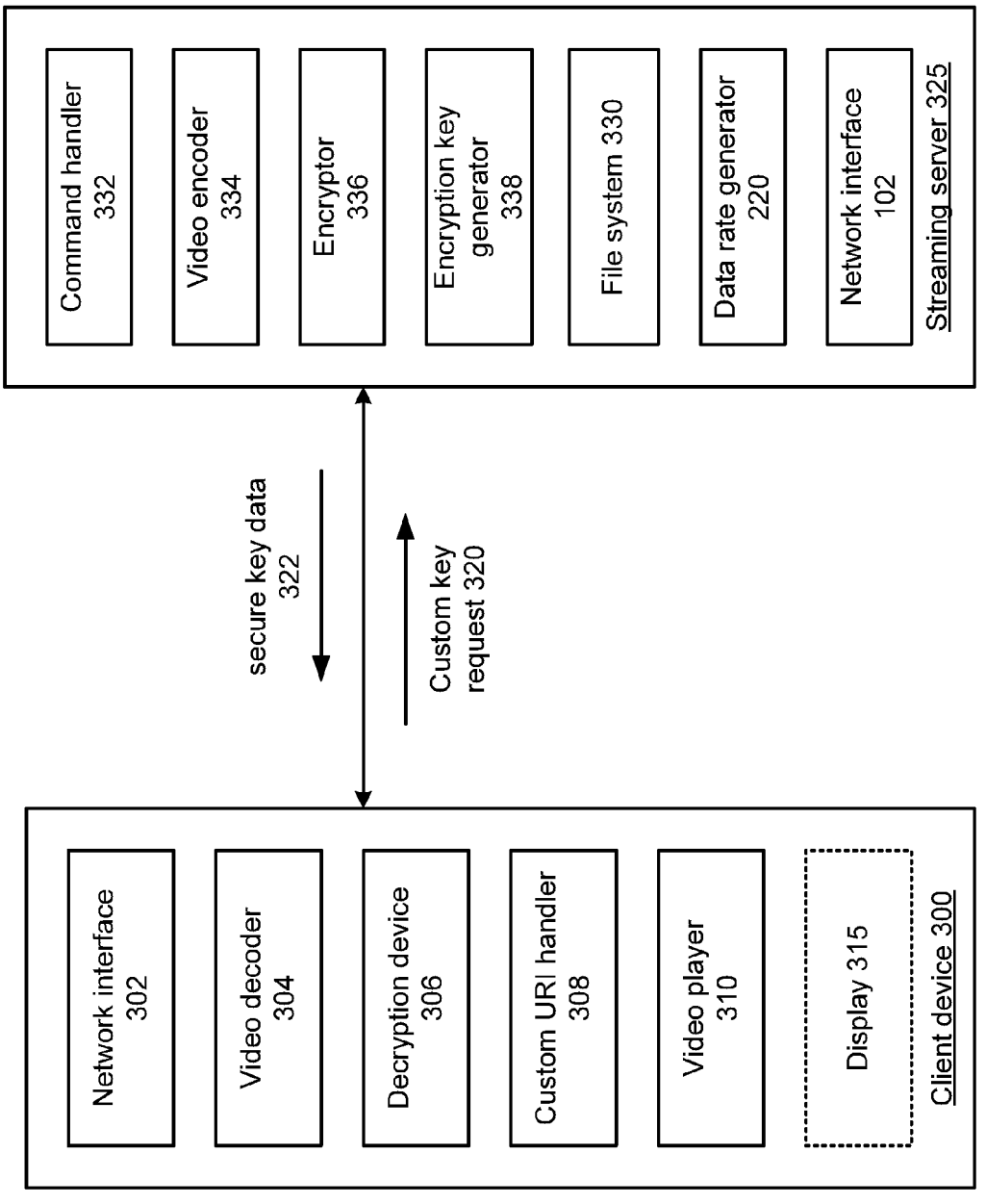

Command handler 332
Video encoder 334
Encryptor 336
Encryption key generator 338
File system 330
Data rate generator 220
Network interface 102
Streaming server 325
secure key data 322
Custom key request 320
Network interface 302
Video decoder 304
Decryption device 306
Custom URl handler 308
Video player 310
Display 315
Client device 300

FIG. 11

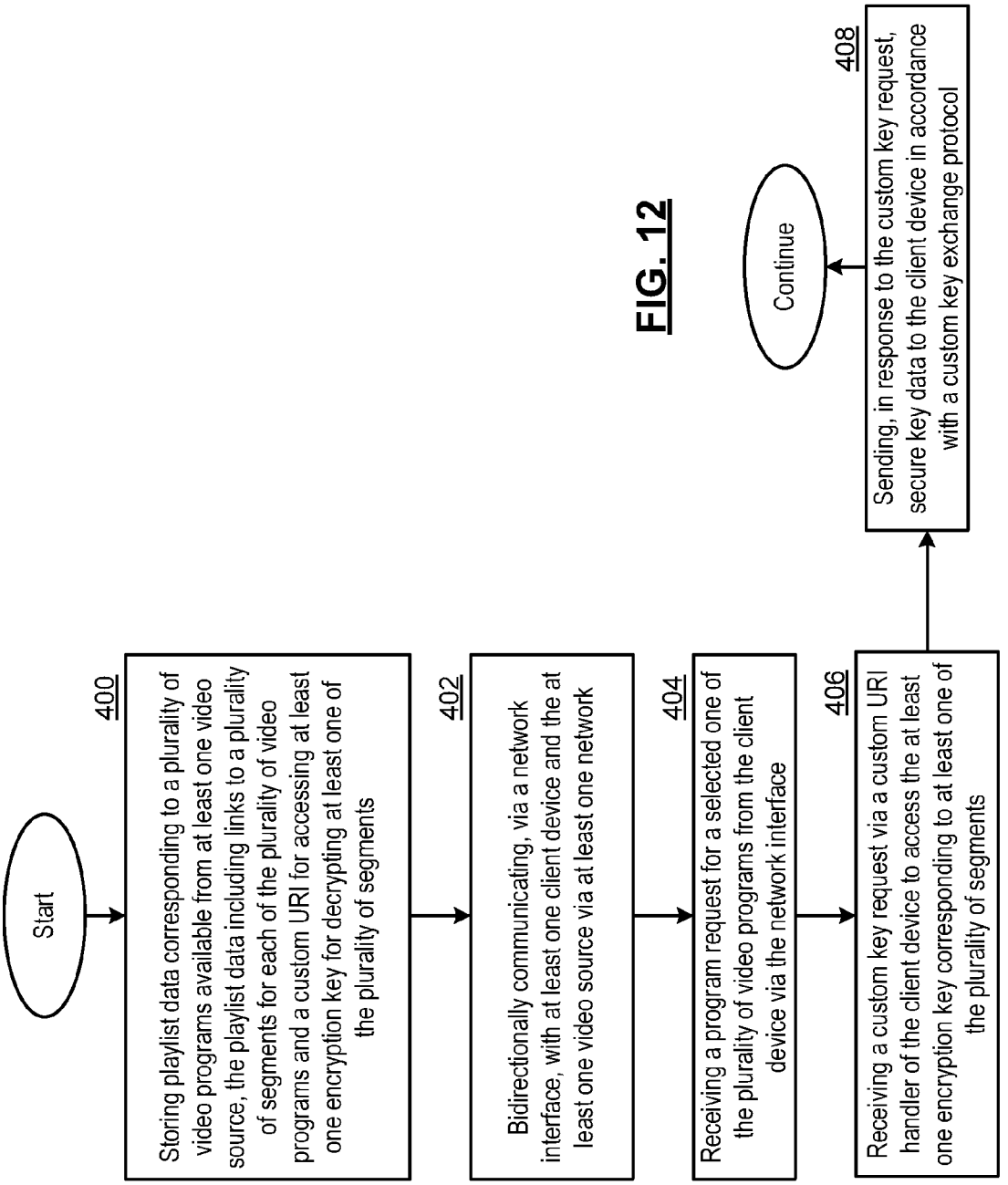

Start
400
Storing playlist data corresponding to a plurality of video programs available from at least one video source, the playlist data including links to a plurality of segments for each of the plurality of video programs and a custom URI for accessing at least one encryption key for decrypting at least one of the plurality of segments
402
Bidirectionally communicating, via a network interface, with at least one client device and the at least one video source via at least one network
404
Receiving a program request for a selected one of the plurality of video programs from the client device via the network interface
406
Receiving a custom key request via a custom URI handler of the client device to access the at least one encryption key corresponding to at least one of the plurality of segments
408
Sending, in response to the custom key request, secure key data to the client device in accordance with a custom key exchange protocol
Continue

FIG. 12

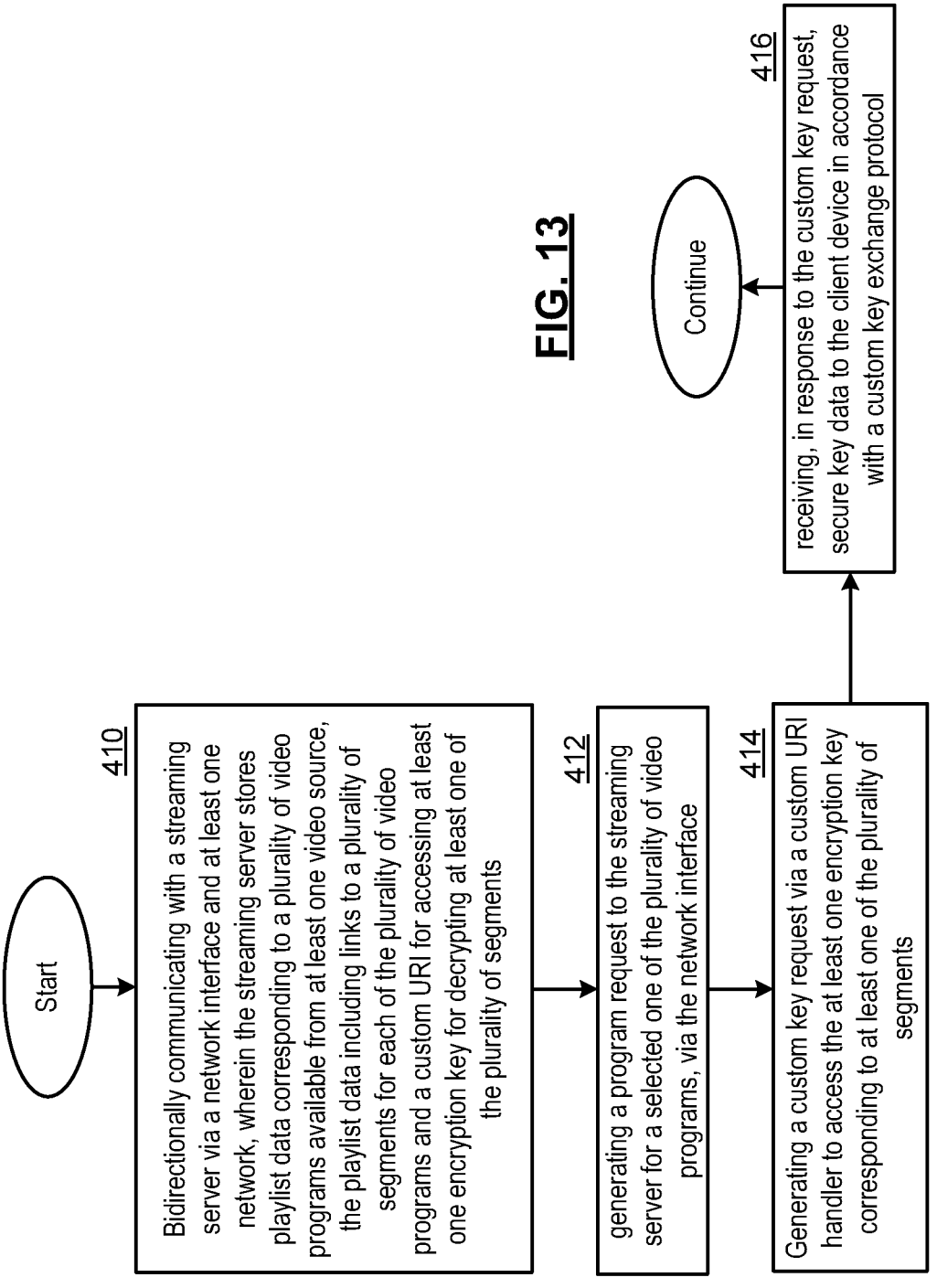

Start
410
Bidirectionally communicating with a streaming server via a network interface and at least one network, wherein the streaming server stores playlist data corresponding to a plurality of video programs available from at least one video source, the playlist data including links to a plurality of segments for each of the plurality of video programs and a custom URI for accessing at least one encryption key for decrypting at least one of the plurality of segments
412
generating a program request to the streaming server for a selected one of the plurality of video programs, via the network interface
414
Generating a custom key request via a custom URI handler to access the at least one encryption key corresponding to at least one of the plurality of segments
416
receiving, in response to the custom key request, secure key data to the client device in accordance with a custom key exchange protocol
Continue

FIG. 13

VIDEO SERVER AND CLIENT WITH CUSTOM KEY EXCHANGE AND METHODS FOR USE THEREWITH

CROSS REFERENCES TO RELATED APPLICATIONS

None

TECHNICAL FIELD OF THE INVENTION

The present invention relates to servers used for streaming media applications including video on demand.

DESCRIPTION OF RELATED ART

The number of households having multiple television sets is increasing, and many users want the latest and greatest video viewing services. As such, many households have satellite receivers, cable set-top boxes, and televisions, et cetera, that provide access to broadcast video services. For in-home Internet access, each computer or Internet device can have its own Internet connection. As such, each computer or Internet device includes a modem. As an alternative, an in-home wireless local area network may be used to provide Internet access and to communicate multimedia information to multiple devices within the home. In such an in-home local area network, each computer or Internet device includes a network card to access an IP gateway. The gateway provides the coupling to the Internet. As an alternative to broadcast video, the Internet provides access to streaming video services. Instead of broadcasting all programming to every customer, each customer receives only those programs that they want, when they want them.

One of the most common ways of streaming continuous video over the Internet today is through the use of the "HTTP Live Streaming" (HLS) protocol. It is developed by Apple Corporation and supported in most of Apple's devices. The HLS protocol operates on a streaming server that uses a standard HTTP (Hypertext Transfer Protocol) web server component. A video encoder takes a source video and encodes it at different bitrates intended for use in different network conditions (high or low capacity) and with different playback devices. The stream is a Motion Picture Expert Group (MPEG2) transport stream divided into multiple segments. Each segment is a compressed piece of the original video of several seconds length. If a segment length is 10 seconds, a one hour movie could be streamed in 360 segments. The segments, put together, form the stream and include the bits from the binary compressed version of the content. Each segment is downloadable over HTTP and accessible via URL. In operation, a client device that wishes to play a streaming video requests and downloads each segment of the stream via separate URL. The segments are decoded by the client device in sequence to play the stream.

A text file with the list of the segment's URLs is called a playlist. A simple playlist can appear as follows:

```
http://myserver.com?segid=100
http://myserver.com?segid=101
http://myserver.com?segid=102
http://myserver.com?segid=103
http://myserver.com?segid=104
#END-OF-LIST
```

where each line is a segment's URL and #END-OF-LIST is an indication of the end of the stream. There are different types of playlists. An Already Recorded Show Playlist is created, when the server has the entire show from the beginning to the end. This type of playlist contains list of URLs for all segments and terminated with #END-OF-LIST tag, indicating that there will be no segments after that point for this stream. The client assumes that all segments are accessible at all times, and could be requested in any order at any moment. This type of play list allows the client to start playback at any random position at the stream, and jump back or forward.

Another form of playlist is a Sliding Window Playlist. This type of playlist is used for live translation/encoding. The playlist contains only a limited number of segments without the termination tag. The client is only able to request segments from this list, without seeing the entire stream. Upon receiving the last segment from the last playlist the client sends request for another playlist expecting to get list of segments beyond the last one it just played back. At the end of the content the server publishes a playlist with #END-OF-LIST tag present, informing the client that the current playlist is the last playlist. Because the client has limited visibility to the stream, this type of playlist doesn't allow the client to perform any trick operation on the stream. Moreover, the client is not even informed about the total length of the stream. An example of a Sliding Window Playlist is presented below:

```
Playlist #1
http://myserver.com?segid=100
http://myserver.com?segid=102
http://myserver.com?segid=103
Playlist #2
http://myserver.com?segid=104
http://myserver.com?segid=105
http://myserver.com?segid=106
Playlist #3
http://myserver.com?segid=107
http://myserver.com?segid=108
http://myserver.com?segid=109
#END-OF-LIST
```

In this example, the client requests Playlist #1, after playing back segment 103 it sends request for another playlist, receiving Playlist #2. After playing back segment 106 it sends request for another playlist, receiving Playlist #3. The playback is done when the client plays last segment from the Playlist #3 and encounters the termination tag.

A further type of playlist is an Event Playlist that is designed for broadcast live events. It has only one playlist, which contains list of the segments from the beginning of the content to the current moment. Whenever a new segment is available it is added to the bottom of the list. The end of list termination tag added as the last line when the event is over. In operation, every time the client reaches the end of current playlist and doesn't encounter a termination tag it requests a new playlist from the server. The event playlist enables the client to perform trick play on the already encoded portion of the content, though, the total length of the program is not available. As the playlist keeps growing over time the amount of traffic and load on the server is getting bigger. By the end of the program the client receives the entire playlist—1200 lines long for a one hour movie with 3 second segments.

One feature of the HLS standard is support for streaming of content with adaptive bitrate. Bitrate is a property of the video stream measured in bits per second. It represents the number of bits in one second of the media file. Higher bitrate streams are bigger, but have better quality. Lower bitrate streams are smaller, and although they have poor quality, because of the small size they could be transferred to the client much faster.

The bitrate is chosen by the client depending on the quality of the network connection. At any time during streaming, the client, depending on the network bandwidth at the moment, may switch to a different bitrate. The new bitrate could be either higher or lower than the current one.

HLS implements adaptive bitrate support by introducing a variant playlist. It is a master playlist with a list of URLs pointing to regular playlists files, described above. Each URL is a reference to a playlist of a particular bitrate. Below is an example of a variant playlist:

```
#EXTM3U
#EXT-X-STREAM-INF:PROGRAM-ID=1, BANDWIDTH=620000
http://myserver.com/hls/movie/620kb/prog_index.m3u8
#EXT-X-STREAM-INF:PROGRAM-ID=1, BANDWIDTH=320000
http://myserver.com/hls/movie/320kb/prog_index.m3u8
```

This variant playlist refers to two regular playlists; the first is for 620 kb/sec content and the second is for 320 kb/sec. At the beginning of a program, the client downloads and parses the variant playlist. The client assumes that segments of all bitrates listed in the variant playlist are accessible at any time. If, for example, the client is experiencing a good network connection, the client may decide to start playback with the highest available bitrate, which is 620 kb/sec in the case above. The client gets the playlist for this bitrate using the URL listed in variant playlist:

http://myserver.com/hls/movie/620 kb/prog_index.m3u8

The client parses the playlist and starts downloading of the segments one by one. If, during downloading of a segment with id=103, the network signal got weaker, the client may not be able to fetch the segment fast enough. In this case the client may fall back to a lower bitrate 320 kb/sec. The client discards the partially downloaded segment with id=103, and starts downloading segments from the lower bitrate playlist starting from the segment with id=103.

An advantage of HLS streaming is that the server is a standard web server. Beyond the application-specific tools needed for segmentation and playlist generation, the software and infrastructure comprises of standard and freely available components that are often already in place. The limitations and disadvantages of HLS and other conventional and traditional approaches will become apparent to one of ordinary skill in the art through comparison of such systems with the present invention.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

FIG. **1** presents a pictorial representation of a content distribution system that in accordance with an embodiment of the present invention.

FIG. **2** presents a block diagram representation of streaming server **50** in accordance with an embodiment of the present invention.

FIG. **3** presents a block diagram representation of playlist data **112** in accordance with an embodiment of the present invention.

FIG. **4** presents a block diagram representation of variant playlist data **114** in accordance with an embodiment of the present invention.

FIG. **5** presents a block diagram representation of an encoder **104** in accordance with an embodiment of the present invention.

FIG. **6** presents a block diagram representation of a rate data generator **220** in accordance with another embodiment of the present invention.

FIG. **7** presents a block diagram representation of streaming server **50'** in accordance with an embodiment of the present invention.

FIG. **8** presents a block diagram representation of an encoder **104** in accordance with an embodiment of the present invention.

FIG. **9** presents a temporal diagram representation of program segments in accordance with an embodiment of the present invention.

FIG. **10** presents a block diagram representation of playlist data **122'** in accordance with an embodiment of the present invention.

FIG. **11** presents a block diagram representation of a client device **300** and a streaming video server **325** in accordance with an embodiment of the present invention.

FIG. **12** presents a flowchart representation of a method in accordance with an embodiment of the present invention.

FIG. **13** presents a flowchart representation of a method in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION INCLUDING THE PRESENTLY PREFERRED EMBODIMENTS

FIG. **1** presents a pictorial representation of a content distribution system in accordance with an embodiment of the present invention. In particular, a streaming video server **50** is capable of accessing and distributing content from one or more video sources **40** to a plurality of client devices such as a television **60**, smart phone, internet tablet or other personal media players **62** and **64**, handheld video player **66**, and personal computer **68**. While specific client devices are shown, video server **50** is capable of accessing and distributing content from one or more video sources **40** to other client devices that can receive and reproduce media content.

The streaming video server **50** uses an on-demand encoding process and a virtual file system. In an embodiment of the present invention, the streaming video server **50** allows adaptable bitrates to be supported with reduced requirements for persistent storage. The streaming video server **50** accesses a virtual file system containing the files needed for streaming: variant playlist files, playlist files, content encryption keys, and video segment files. Most of the video data in the file system is not stored in a real non-volatile storage device; instead the data may be generated only when necessary due to a read operation in request for particular video content from a client device.

In the example shown, the video source or sources **40** are external to the system and coupled to the streaming video server **50** to provide coded audio-video streams via a secure channel, such as a secure socket layer (SSL) connection, a private network, a virtual private network or other secure connection. The video source or sources **40** can have two types of content: live and pre-recorded. The video source **40** can be a live video source such as a broadcast cable network, a broadcast satellite network, a broadcast television network, an IP television distribution system, a broadcast mobile network, a video conferencing service or other source of live video. Example of video sources **40** of prerecorded content include a video on demand source such as a YouTube, Hulu, Netflix, or other streaming video source, a cable or IP television video on demand network, a digital video recorder, UPnP media server, camcorder, personal computer or other source of stored video. The two types of content can be

handled differently when limited network bandwidth causes the rate of data transfer to the client to be lower than the encoding rate. For live content, the streaming system discards portions of the audio-video stream that could not be transferred within some time limit. This ensures that the delay between transmission at the source, and decoding and playback at the client is bounded. For a video conference, this means that conversations will not be hampered by excessive delays, but there may be discontinuities in the conversation when the network slows suddenly. Pre-recorded content can be streamed in a continuous manner. If the network slows suddenly and the client runs out of data to decode, it handles this in the short term by waiting for more data, and in the longer term by selecting a variant playlist with a lower bitrate.

In operation, the streaming video server **50** transcodes or decodes and re-encodes the content from a video source **40** to the bitrates corresponding to the playlists. In this fashion, encoding of a video program is performed only when it is needed in response to a client's request for that particular program. Therefore, videos that are made available by the streaming video server **50**, but never requested by the client, do not incur the overhead of encoding.

When streaming is initiated, a video encoder of streaming video server **50** is allocated for the session. The encoder outputs a continuous audio-video bitstream and then a post-processing step breaks the streaming into the required segments. In addition, the encryption key generation process can be performed on-demand. This allows the keys to not be saved to a storage device, protecting the security of the key from being read without authorization. For increased content security, the keys can be generated randomly and are never used for more than one streaming session. The encryption process can also be performed on-demand.

In operation, the streaming video server **50** produces segments in-order, i.e. **100**, **101**, **102** and so on. This works well if the requests from the client come in order. However, every request out of order requires repositioning in the input stream and therefore restarts the transcoder from this new position. This action takes can lead to a delay of 10-20 seconds. If HLS bitrate control were implemented as per specification, each change of bitrate by the client would result in a request of an out of order segment, leading to a delay. Further, each delay could make the client to think that there is not enough network bandwidth, and the client could respond by lowering the bitrate even more. Ultimately, this could result where the client continues to switch the bitrate until the lowest possible bitrate is reached.

To address this issue, the streaming video server **50** presents a variant playlist that indicates only a single bitrate, i.e. a single variant (a single entry on the list—as opposed to multiple bit rate choices). This eliminates attempts at rate control from the client side. Instead, the streaming video server **50** measures the network bandwidth on the server side, and adjusts the bitrate of the generated video stream according to the current network conditions. As the client doesn't perform any bitrate control, it never sends an out-of-order request, and the transcoder is never restarted during bitrate adjustment.

Streaming video server **50** can further include one or more features of the present invention described further in conjunction with FIGS. **2-13** that follow.

FIG. **2** presents a block diagram representation of streaming server **50** in accordance with an embodiment of the present invention. As shown, streaming video server **50** includes a command handler **100**, one or more video encoders **104** and video encryptors **106**, and an encryption key generator **108**. Streaming video server **50** also includes virtual file system **110** that stores playlist data **112** that includes a content index corresponding to the video programs available from the video source or sources **40** as well as a segment playlist for each video program that includes a list of addresses for each segment of that video program. Virtual file system **110** further stores variant playlist data **114** that indicates a single entry for streaming each of the plurality of video programs. The URIs in the content index, variant playlist, and segment playlist may or may not correspond to actual files as in a traditional web server or streaming server that serves files stored on hard drive. These addresses are generated by the streaming video server **50** and recognized as references to the virtual files when the client makes the HTTP request for a particular video program. This applies to the URIs for the lists themselves and also for the encrypted segment data and encryption keys. When a request is received for a "file" in the virtual file system, the server generates the appropriate response depending on the actual request. For example, (a) responding with the content index, variant playlist, segment playlist data using information stored in memory, (b) generating a random encryption key, storing it to memory (for subsequent segment requests), and sending it in the response to the client, (c), initiating video transfer from a source, initiating the encoding and segmentation, sending the first segment in the response to the client, (d) for a previously initiated transfer, encoding, segmenting, and return the next segment to the client.

A network interface **102** is included to bidirectionally communicate with at least one client device via network **30** and to bidirectionally communicate with the at least one video source, such as via a secure channel of network **30** or another network. The network interface **102** can include a modem, transceiver or other network interface adaptor that implements a serial or parallel connection such as an Ethernet connection, Universal Serial Bus (USB) connection, an Institute of Electrical and Electronics Engineers (IEEE) 1394 (Firewire) connection, small computer serial interface (SCSI), high definition media interface (HDMI) connection or other wired connection that operates in accordance with either a standard or custom interface protocol. In addition or in the alternative, the network interface **102** can include a wireless link for coupling to the network **30** and/or video source or sources **40** either directly or indirectly through one or more devices that operate in accordance with a wireless network protocol such as 802.11a,b,g,n (referred to generically as 802.11x), Bluetooth, Ultra Wideband (UWB), 3G wireless data connection, 4G wireless data connection or other wireless connection that operates in accordance with either a standard or custom interface protocol.

In operation, the command handler **100** coordinates the encoding and encryption processes with a client's requests for video content. For example, the command handler **100** receives a HTTP request for a selected one of the plurality of video programs from the at least one client device via the network interface **102**. In response to the request, the selected one of the plurality of video programs is retrieved from the video source or sources **40**, via the network interface. For example, the command handler can access the playlist data **112** to determine the universal resource identifier (URI) or other address for retrieving the selected one of the plurality of video programs from the video source or sources **40**.

The command handler **100** retrieves the selected one of the plurality of video programs. A plurality of encoded segments are generated from selected video program, via a video encoder **104**, at a selected bit rate. The video encoder **104** can include one or more encoders or transcoders that receive an encoded video program from the video source or sources **40** and that decodes and re-encodes or otherwise transcodes the

audio and/or video of the program into the scale, resolution, and digital compression format, and at the selected bitrate for the requesting client device. In particular, the video encoder **104** can operate in accordance with a motion picture expert group (MPEG) format such as MPEG2, MPEG4 part 10, also referred to as H.264. Other video formats such as VC1, digital video (DV), etc., could likewise be employed. In an embodiment of the present invention, the video source or sources **40** contain unsegmented videos. Upon the client request of the first segment for a particular video and bitrate, the streaming video server **50** starts the retrieval of the video from the corresponding video source **40**, and performs the encoding and segmentation. The segmentation can be done before or after the encoding, though it can be more practical to do the encoding first, then the segmentation.

Encrypted segments are generated from the encoded segments, via the video encryptor **106**, based on an encryption key. The encrypted segments are then stored as video segments **116** that are then sent, via the network interface **102**, as a streaming video signal to the at least one client device that requested the video program. The video encryptor **106** can operate in accordance with one or more cryptography algorithms such as data encryption standard (DES), Rivest, Shamir, Adelman (RSA), elliptical curve cryptography (ECC), Advanced Encryption Standard (AES) or other algorithm.

Streaming server module **50** includes an encryption key generator that generates the encryption key in response to the request. As discussed in conjunction with FIG. **1**, the encryption key generator **108** generates encryption keys on-demand. This allows the keys to not be saved to a storage device, protecting the security of the key from being read without authorization. For increased content security, the keys can be generated randomly and are used for only one streaming session. In theory, while identical encryption keys could reoccur randomly, each encryption key is nevertheless practically or substantially unique to the request.

In an embodiment of the present invention, the rate data generator **220** generates rate data that indicates the selected bit rate. In operation, the rate data generator selects the bit rates based on channel information from network **30** pertaining to a communication channel between the network interface and the client device that generated the request. The channel information can include network bandwidth data, network utilization data, and/or other data including a channel type, expected bit rate, current actual bit rate, etc. As the bit rate is adjusted, the video encoder **106** encodes each current segment at the selected rate.

The command handler **100**, video encoder **104**, video encryptor **106**, encryption key generator **108** rate data generator **220** and virtual file system **110** can be implemented via one or more processing devices and one or more memory devices. Such processing devices can include a microprocessor, micro-controller, digital signal processor, microcomputer, central processing unit, field programmable gate array, programmable logic device, state machine, logic circuitry, analog circuitry, digital circuitry, and/or any device that manipulates signals (analog and/or digital) based on operational instructions that are stored in a memory. The memory can include a hard disc drive or other disc drive, read-only memory, random access memory, volatile memory, non-volatile memory, static memory, dynamic memory, flash memory, cache memory, and/or any device that stores digital information. Note that when the processing device implements one or more of its functions via a state machine, analog circuitry, digital circuitry, and/or logic circuitry, the memory storing the corresponding operational instructions may be embedded within, or external to, the circuitry comprising the state machine, analog circuitry, digital circuitry, and/or logic circuitry.

The streaming video server **50** has additional advantages over convention servers. The requirements for storage are reduced for the video segments, variant playlist, and playlists. This is especially important for embedded systems with limited storage capabilities. In addition, since the encryption process is performed on-demand like the encoding process, the key can be protected such that it can be accessed only by the intended client device, as opposed to all potential clients. Furthermore, the key itself can be changed while streaming is in progress, and this decision can be made during run-time as needed. These content protect features are especially important for premium content such as pay-per-view video. Further, the risk of unauthorized access to unencrypted video streams is reduced since they are never stored in encrypted or unencrypted form to a persistent storage device where they may be accessed by attackers. Also, live and pre-recorded video content can be handled differently. Streams from live sources will not suffer large delays.

FIG. **3** presents a block diagram representation of playlist data **112** in accordance with an embodiment of the present invention. FIG. **4** presents a block diagram representation of variant playlist data **114** in accordance with an embodiment of the present invention. In the example shown, playlist data **112** includes content index **120** a title of all available video selections from any of video sources **40**, and a URI address for accessing the variant playlist data **114** for each program. The content index does not have to be in a particular format, as long as the client devices and the streaming video server **50** use the same format or the formats can be translated to be compatible. Example formats include JSON, XML, plain text, etc. Other address formats could likewise employed including a file addressing scheme, an IP address, or other logical or physical addressing. In addition, the while specific video on-demand programs are presented, as previously discussed, live video programming could be retrieved, segmented, encoded and encrypted on demand for delivery in response to a client request.

In addition, playlist data **112** includes a segment playlist **122** for each video program and for each bitrate. Each segment playlist includes a segment number and address for each segment of the video program and optionally an address of an encryption key used for encrypting that particular segment. Again, while URIs are shown, Other address formats could likewise employed including a file addressing scheme, an IP address, or other logical or physical addressing.

The virtual file system also contains variant playlists for each video program in the content index. Each variant playlist includes an address (such as the URI shown) for the segment playlists, which are also contained in the virtual file system with a single entry.

In one example of operation, the streaming video server maintains playlist data **112** that includes a content Index that is served to the client upon its request. The streaming video server **50** can, for example, query each of the video sources **40** or its list of videos, then aggregate them to the create such a content index. The content index contains, for each item, the URI of the variant playlist. The client selects one item (e.g., via user input), then makes the HTTP request for the URI corresponding to that variant playlist for that item. The variant playlist contains the segment playlist URI for a single "phantom" bitrate, as shown in FIG. **4**. As discussed in conjunction with FIG. **1**, this forces the client to choose the single variant entry and eliminates the adaptation of the bit rate from the client side—in lieu of the server side adaptation of the bit

rate. The client makes an HTTP request for the playlist (the only item on the list). The segment playlist contains the URIs for each segment's data and each segment's encryption key.

The URIs in the content index, variant playlist, and segment playlist do not correspond to actual files as in a traditional web server or streaming server that serves files stored on hard drive; the URIs are generated by the server and recognized as references to the virtual files when the client makes the HTTP request. This applies to the URIs for the lists themselves and also for the segment data and encryption keys. When a request is received for a "file" in the virtual file system, the server generates the appropriate response depending on the actual request. For example, (a) responding with the content index, variant playlist, segment playlist data using information stored in memory, (b) generating a random encryption key, storing it to memory (for subsequent segment requests), and sending it in the response to the client, (c), initiating video transfer from a source, initiating the encoding and segmentation, sending the first segment in the response to the client, (d) for a previously initiated transfer, encoding and segmentation, return the next segment to the client. As shown the variant playlist data includes only a single entry for a particular title, a group of titles, for all programs from a particular video source **40** or from all video sources.

The streaming video server **50** provides additional advantages over a conventional HLS-based server system. Multiple video encoders **104** can be present in order to meet the simultaneous use requirements of on-demand transcoding for multiple client devices. The encoded data is generated on as-needed basis and reducing the need for persistent storage. Encryption keys can be generated on an as-needed basis and never stored except temporarily in volatile memory, also saving storage. By not storing encoded data and encryption keys, content security is improved. Also, live and pre-recorded content can be handled differently, resulting in improved user experience.

A conventional HLS-based server system must store the video for all bitrate settings. The requirement for storage capacity grows with the number of bitrate settings and duration of the video. The data must be stored even though it may never be requested by the client, because it can't be absolutely determined at encoding time which particular segments will be used by the clients. In the present system, the data resulting from video transfer from a video source **40**, encoding, key generation, and encryption are not stored to persistent storage (e.g. a hard drive). Transfer, encoding, segmentation, and encryption on a source video can be deferred until that video is requested by the client.

In addition, in a conventional HLS-based server system, the bitrates for the video must be set before the encoding process starts. Some knowledge of the expected network capacity and playback device types is required in order to select the appropriate bitrates. Typically, three bitrates are used: one low bitrate setting of approximately 64 kbps, and two higher settings between 100 and 500 kbps. Setting the bitrates at encoding time means that the target use cases are also set. Any unexpected cases (e.g., very high network capacity, a new client device) are not addressed. When the video segments are encrypted, an encryption key must be selected that is to be used by all clients.

In contrast, the streaming video server **50** can employ adaptive bitrates without having to encode and store the encoded and encrypted video segments for an entire program at all of those bitrates prior to streaming. In an embodiment of the present invention, prior to streaming, little needs to be known about the client device and the possible network conditions. In addition, since bitrate settings are adjusted to adapt to current conditions adjustments and generated on the fly, these adjustments can be made with a fine granularity over the full range required. This reduces the distracting effect of the video and audio quality changing greatly from one segment to the other due to a large change in bitrate. More importantly, the adaptive bitrate feature allows the network usage to be optimized for the current conditions. That is, it is more likely that the selected bitrate is the maximum allowed by the network connection between the server and client, thus maximizing the video and audio quality for the end user.

FIG. **5** presents a block diagram representation of an encoder **104** in accordance with an embodiment of the present invention. In this embodiment, the video encoder **104** encodes the selected video program **200** into encoded video program segments **204**. Video encryptor **106** encrypts the encoded video programs segments **204** into encrypted video program segments **206** based on an encryption key, such as a key from encryption key generator **108**. The encrypted video program segments **206** are transmitted over network **30** via network interface **102**. In operation, rate data generator **220** generates rate data **222** based on transmission feedback data **224** from the network interface **102** that reflects the channel conditions. Transmission feedback data **224** can also include data from the client device **60**, **62**, **64**, **66** or **68** that indicates information regarding that client device. Examples of such client data includes a current one of a plurality of device states, such as a client device operating system, video display window size (minimized, partial or full screen) or a volume setting that can be used to adjust the video resolution, or audio encoding depth, the number of audio channels or be used to decide whether to or not to include audio information in the stream. The rate data **222** can also be optionally based on context data **202** that relates to the content of the video program **200**. The context data **202** can indicate information derived from the video program **200** or the video source **40** such as the genre of video (e.g., news, sit com, music, cartoon, video conference), the number of audio channels and/or other information regarding the characteristics, properties or format of the video program **200**.

The video encoder **104** encodes the video program segments based on one or more encoding parameters that are adjusted in response to rate data **222** that relates to the streaming session for the selected video program.

As discussed in conjunction with FIG. **2**, video encoder **104** can operate in accordance with a motion picture expert group (MPEG) format such as MPEG2, MPEG4 part 10, also referred to as H.264. Other video formats such as VC1, digital video (DV), etc., could likewise be employed. In an embodiment of the present invention, the video program **200** can be segmented before or after encoding. Video encoder **104** can be implemented via one or more processing devices and one or more memory devices. Such processing devices can include a microprocessor, micro-controller, digital signal processor, microcomputer, central processing unit, field programmable gate array, programmable logic device, state machine, logic circuitry, analog circuitry, digital circuitry, and/or any device that manipulates signals (analog and/or digital) based on operational instructions that are stored in a memory. The memory can include a hard disc drive or other disc drive, read-only memory, random access memory, volatile memory, non-volatile memory, static memory, dynamic memory, flash memory, cache memory, and/or any device that stores digital information. Note that when the processing device implements one or more of its functions via a state machine, analog circuitry, digital circuitry, and/or logic circuitry, the memory storing the corresponding operational instructions may be embedded within, or external to, the

circuitry comprising the state machine, analog circuitry, digital circuitry, and/or logic circuitry.

In operation, the streaming server **50** responds to the segment requests by encoding the source content at the selected bitrate. The encoding process is performed on-demand, therefore the encoding parameters can be adjusted to conform with the rate data **222** that reflects the conditions of the current streaming session. In response to the rate data **222**, the video encoder **104** can adaptively choose or otherwise adjust the overall average bitrate of a segment, and for a selected overall average bitrate, the average bitrate of the audio content and the average bitrate of the video content. In addition, the video encoder **104** can adaptively choose or otherwise adjust other encoding parameters such as the output video resolution, the output video frame rate, the number of encoded audio channels, etc.

FIG. **6** presents a block diagram representation of a rate data generator **220** in accordance with another embodiment of the present invention. In particular, rate data generator **220** includes a rate data processor **230** that operates based on transmission feedback data **224** and optionally based on context data **202** to generate rate data **222**. The rate data processor **230** can be implemented via one or more processing devices and one or more memory devices. Such processing devices can include a microprocessor, micro-controller, digital signal processor, microcomputer, central processing unit, field programmable gate array, programmable logic device, state machine, logic circuitry, analog circuitry, digital circuitry, and/or any device that manipulates signals (analog and/or digital) based on operational instructions that are stored in a memory. The memory can include a hard disc drive or other disc drive, read-only memory, random access memory, volatile memory, non-volatile memory, static memory, dynamic memory, flash memory, cache memory, and/or any device that stores digital information. Note that when the processing device implements one or more of its functions via a state machine, analog circuitry, digital circuitry, and/or logic circuitry, the memory storing the corresponding operational instructions may be embedded within, or external to, the circuitry comprising the state machine, analog circuitry, digital circuitry, and/or logic circuitry.

In an embodiment, the rate data processor **230** operates based on transmission feedback data **224** that includes network bandwidth data **226** and network utilization data **228**. Network bandwidth data **226** represents a number of bytes per second transferred over the network connection. For example, this quantity can be calculated based on an average number of bytes sent to the client in the last 15 seconds. It can be measured in bytes per second and calculated as a running average such as an unweighted average, an exponentially weighted moving average, a filtered average or other mean, median or other average. Network utilization data **228** can be calculated based in the percentage of time spent in data transmission in a particular second—i.e. what part of that second the network interface **120** was busy with sending data to network **30**. For example, this quantity can be calculated based on by measuring the amount of time spent in a socket write( ) function during each second. Spending 500 ms of a particular second in writing data to the channel yields a 50% utilization.

The rate data **222** can be calculated based on the value of the variable "bitrate" in the following algorithm.

```
if ( aUtilisation < mTargetUtilisation )
{
    // try to speed-up
    if ( aUtilisation < 10 )
    {
        // less than 10% utilisation is not reliable, try to use double
rate than the current speed
        bitrate = aSpeed * 2;
    }
    else
    {
        realSpeed = aSpeed * 100 / aUtilisation;
        bitrate = realSpeed * mTargetUtilisation / 100;
    }
}
else
{
    // try to slow down
    bitrate = aSpeed * mTargetUtilisation / aUtilisation;
}
```

where aUtilization and aSpeed are current network utilization (network utilization data **228**) and current network speed (network bandwidth data **226**) and mTargetUtilization is a maximum percentage of the total reachable bandwidth which could be used for transmission streaming data. Reserving some amount to account for errors in bitrate calculation, and for different overheads such us HTTP headers etc., mTargetUtilization can be set at 90% or other limit.

In addition, to the algorithm above, the rate data processor **230** can adjust the data rate **222** based on a minimum data rate. In particular, the HLS protocol prohibits changing of any parameters of the stream. Particularly, if the stream contained both video and audio, each of its segments of any bitrate should always contain both video and audio disregarding of how low the bitrate is. Moreover, the audio parameters, including the bitrate, stay the same for all bitrates for current stream. Therefor the lowest reachable bitrate may be limited based on the bit rate required to send the audio track. As the video track couldn't be completely removed, in an embodiment, to get as close to the audio bitrate as possible, the encoded video program segments can be replaced with a still image of the video program **200**, a standard still image or other still image. A bitrate of such a video stream should be close to zero, which makes the total bitrate of the stream equal to audio bitrate.

At the beginning of a video program, the rate data generator can adjusts the data rate **222** based on an initial data rate that starts the stream at the first segment. The initial data rate can be fixed as a nominal data rate, estimated based on partial transmission feedback data **224** and/or generated based on context data that indicates properties of the selected one of the plurality of video programs.

While the rate data **222** can be generated as described above, other techniques can likewise be employed. The rate data **222** be generated based on a bandwidth assessment or other bandwidth test performed in response to the request for the selected video program **200**. A channel bandwidth test can be performed prior to transmission of the first segment. For example, prior to requesting the first segment, the client device **60**, **62**, **64**, **66** or **68** can request a URI that is specifically used to perform the channel bandwidth test. The streaming server **50** recognizes this request and responds with a test signal to the requesting client device. The transfer rate of the test signal can be measured by the streaming server **50**. For example, the response to the variant playlist request can be padded with content that is to be ignored by the requesting client device (normal variant playlist content still exists). This can be done by placing whitespace characters at the end, or inserting lines that start with the comment character '#'. The

amount of data can be chosen so the total size of the variant playlist is suitable for a channel bandwidth test while reducing the time delay in starting the playback of the selected video program to the user. Using too much data could slow the user experience, while using too little data could reduce the accuracy of the test result. The transfer rate of the variant playlist is measured by the streaming server **50**.

FIG. **7** presents a block diagram representation of streaming server **50'** in accordance with an embodiment of the present invention. In particular, a streaming server **50'** is presented that operates in a similar fashion to streaming server **50** and that includes many similar elements to streaming server **50** that are referred to by common reference numerals. Streaming server **50'** includes a segment memory **240** that includes one or more initial video program segments for each title in the content index that can be used to initialize the video stream when the first video segments are being produced. This reduces the latency period of the stream—speeding up the time to transmission of the first segments since there is no need to wait for encoding or transcoding—these initial segments can be retrieved directly from the segment memory. Further details of this configuration including optional functions and features will be described in conjunction with FIGS. **8** and **9** that follow.

FIG. **8** presents a block diagram representation of an encoder **104** in accordance with an embodiment of the present invention. A similar structure is presented to FIG. **5** that includes many similar elements that are referred to by common reference numerals. This configuration includes a segment memory **240** that stores one or more stored initial video program segments for each video program in the content index. When a particular video program **200** is requested, the initial segment or segments of the stream can be retrieved from the segment memory **240** as stored initial program video segments **242** that are passed by multiplexer **244** to video encryptor **106**. At the same time that these stored initial video program segments **242** are being retrieved, the video encoder **104** can begin encoding or transcoding the video program **200** to generate encoded video program segments **204**. In an embodiment, the video encoder **104** begins the production of encoded video program segments **204** at a point in time before a request for the corresponding segment arrives. In this fashion, if/when the request for the segment arrives, the video encoder **104** is prepared. In this configuration, a buffer of the video encoder **104** (not expressly shown) is used to store the encoded video segment **204**.

The multiplexer **244** can switch the stream from the stored initial video program segments **242** to the encoded video program segments **204** when the stored initial video program segments **242** are exhausted. In other mode of operation, the multiplexer **244** can switch the stream from the stored initial video program segments **242** to the encoded video program segments **204** when the first encoded video program segments **204** is complete and corresponding prior segment from the stored initial video program segments **242** has been passed to the video encryptor **106**.

FIG. **9** presents a temporal diagram representation of program segments in accordance with an embodiment of the present invention. In particular, a plurality of segments (001-009) of a video program that are output from the multiplexer **244** are shown. In this example when a request for a first segment (001) of a particular video program arrives the video encoder **104** begins the production of encoded video program segments **204** beginning at segment (004)—at a point in time before a request for the segment (004) arrives. The multiplexer **244** begins feeding the first three segments (001-003) of the video program as the stored initial video program segments **242** during the time the encoder **104** is initializing. By the time the last stored segment (003) is passed to the video encryptor **106**, the next segment (004) is ready from the video encoder **104** and when a request for the segment (004) arrives, the multiplexer **244** can switch to the encoded video program segments **204**.

In the example shown, the multiplexer **244** generates output segments to the video encryptor as the initial video program segments (001-003) during an initial latency period of the video encoder in producing a first encoded video segment (004)—the next segment in a temporal sequence of the video program segments. Said another way, the initial video program segments (001-003) cover an initial temporal period of a selected video program corresponding to an initial latency period of the video encoder **104** in producing a first segment of the encoded video segments (004).

The number of stored initial program segments **242** can be selected based on their duration to cover or more than cover any such latency period. In the example described above, segments (004-005) may also be stored in the segment memory **240** for use if necessary, depending on the selected encoding bit rate. If a video segment is requested by the client device that has already been encoded and the corresponding stored initial video program segment has not been sent, the multiplexer **244** can switch to sending the encoded video program segment corresponding to the request in lieu of the stored initial video program segment of this number.

It should also be noted that transmission feedback data **244** can be generated during the transmission of the stored initial video program segments in order to more quickly generate meaningful rate data **222**.

FIG. **10** presents a block diagram representation of playlist data **295** in accordance with an embodiment of the present invention.

With the HLS standard, a playlist presents a standard URL for the AES key—used in protecting one or more segments—from the HLS playlist. The AES key under this standard is in plain text over http or https protocols. As such an adversary can also gain access to the same key and use that to decrypt the protected content. Playlist data **295** is shown for use in conjunction with a streaming server that operates in a similar fashion to streaming server **50** or **50'**, but using a custom key exchange protocol in place of the default mechanism described in the HLS standard.

In operation, playlist data **295** is presented that employs custom URIs, such as a custom encryption key URLs to access the encryption key for each encoded segment of each video program. A client device, such as client device **60**, **62**, **64**, **66** or **68** accesses the encryption key for each segment using a custom URI (or URL) handler that is registered with the operating system of the client device and that operates in conjunction with custom key exchange protocol.

Further details regarding the operation of the modified server and client device, including one or more optional functions features are described further in conjunction with FIGS. **11-13** that follow.

FIG. **11** presents a block diagram representation of a client device **300** and a streaming video server **325** in accordance with an embodiment of the present invention. In particular a streaming server **325** such as streaming server **50**, **50'** or other streaming server is presented for use in conjunction with a client devices **60**, **62**, **64**, **66**, **68** or other client devices. As discussed in conjunction with FIG. **10**, streaming server **325** and client device **300** operate in conjunction with a custom key exchange protocol in place of the default mechanism described in the Http Live Streaming standard.

A network interface **102** bidirectionally communicates with client device **300** and video sources either directly or via one or more networks not expressly shown. In this embodiment, streaming server **325** includes a file system **330** that stores playlist data, such as playlist data **295**, corresponding to a plurality of video programs available from at least one video source. The file system **310** can be virtual file system **110** that operates in conjunction with command handler **332** and an optional data rate generator **220** by: retrieving the selected video programs from a video source via the network interface **102** in response to the program request; segmenting and encoding the selected video program into a plurality of encoded segments via video encoder **334**; generating encrypted segments from the plurality of encoded segments, via encryptor **336**, in accordance with an encryption key generated by encryption key generator **338**; and sending, via the network interface **102**, a streaming video signal to the client device **300** that includes the plurality of encrypted segments. While described above in context of a virtual file system, file system **330** optionally operates in a more convention fashion with stored program segments.

As discussed in conjunction with FIG. **10**, the playlist data of file system **310** includes links to a plurality of segments for each of the plurality of video programs and a custom universal resource indicator (URI) for accessing at least one encryption key for decrypting at least one of the plurality of segments. In particular, the encryption key or keys may be the same keys used to encrypt the video segments. In any case, the knowledge of the encryption keys at a client device allows a client device to decrypt the encrypted segments of the video program for decoding and/or playback.

In operation, command handler **332** receives a program request for a selected one of a plurality of video programs from client device **300** via the network interface **102** and further receives a custom key request **320** via custom URI handler **308** of the client device **300** to access the an encryption key corresponding to one of more segments of the selected program. In response to the custom key request **320**, the command handler **332** sends secure key data **322** to the client device **300** in accordance with a custom key exchange protocol.

In an embodiment, the streaming server **325** includes an encryption key generator **338** that generates encryption keys on-the-fly in response to the custom key request **320** that are substantially unique to the custom key request **320**. The command handler **332** operates in conjunction with an encryptor **336** to generate the secure key data **322** by encrypting the encryption key via DES, RSA, ECC, AES or other algorithm.

The command handler **332**, video encoder **334**, video encryptor **336**, encryption key generator **338** and virtual file system **330** can be implemented via one or more processing devices and one or more memory devices. Such processing devices can include a microprocessor, micro-controller, digital signal processor, microcomputer, central processing unit, field programmable gate array, programmable logic device, state machine, logic circuitry, analog circuitry, digital circuitry, and/or any device that manipulates signals (analog and/or digital) based on operational instructions that are stored in a memory. The memory can include a hard disc drive or other disc drive, read-only memory, random access memory, volatile memory, non-volatile memory, static memory, dynamic memory, flash memory, cache memory, and/or any device that stores digital information. Note that when a processing device implements one or more of its functions via a state machine, analog circuitry, digital circuitry, and/or logic circuitry, the memory storing the corresponding operational instructions may be embedded within, or external to, the circuitry comprising the state machine, analog circuitry, digital circuitry, and/or logic circuitry.

Client device **300** includes a network interface **302** to bidirectionally communicate with streaming server **325**, a custom URI handler **308**, a video decoder **304**, a decryption device **306** and a video player **310**. The video play **310** operates in response to commands of a user received via a user interface such as a touch screen, remote control device or other device by generating a program request to the streaming server **325** for a selected video program that is sent to the streaming server **325** via the network interface **302**. The video player **310** further generates a custom key request **320** via the custom URI handler **308** for encryption keys corresponding to one or more segments of the selected video programs. The video player **310** receives, in response to the custom key request **320**, secure key data **322** from the streaming server **325** in accordance with a custom key exchange protocol and decrypts the secure key data **322** via the decryption device **306** to extract the encryption keys. The video player **310** also receives and decrypts the encrypted video segments from the streaming server **325** via the decryption device **306** and the encryption keys, to generate encoded segments. The video player **310** then decodes the encoded segments, via the video decoder **304**, to generate at least one decoded segment for playback on display device **315**, for storage or transfer to an external display device via a display device interface (not expressly shown). While described above as a video player **310**, any streaming media player can be used in a similar fashion.

The customer URI handler **308** is registered with an operating system of the client device **300**. The operating system identifies a format of the custom URI and invokes the custom URI handler **308** in response to identifying the format of the custom URI. In an embodiment, the encryption keys include includes a plurality of encryption keys corresponding to the plurality of segments of the selected video program.

The operation of streaming server **325** and client device **300** can be described in conjunction with the following example. As discussed, a custom URI scheme is introduced in place of a standard URL such as "http" or "https". The streaming server **325** encodes the path (URI) for the key using this custom protocol. The key URI in the playlist data **322** follows a construct such as the following:

<custom_scheme>://server:port/path?other_identifiers

The <custom_scheme> can be a custom format—anything other than the well-known schemes used in URLs. In the examples shown in FIG. **10**, the custom scheme is indicated by "mttp" with the server and path identified by "Morega.key-.com/bwt0000000X". It should be noted that the particular custom URL shown and the basic format presented above are merely examples of the many options for custom URI/URL formats.

When the video player **310** encounters the custom URI for the key, it will invoke the custom URI handler **308**. The custom URI handler **308** then makes a call to the streaming server **325** in the form of custom key request **320**. This call can be made via any networking protocol. The custom URI handler **308** then obtains the key as secure key data **322** in protected form, decrypts the key and returns the key data to the video player **310**. The video player **310** then proceeds to decrypt the content for the received segment using this key. Any interception of the secure key data **322** between the custom URI handler **308** and the streaming server **325** poses no security threat since the key is sent in protected form. Only the custom URI handler **308** knows how to extract the HLS key from the exchanged data. It should be noted that the protection of the key via secure key data **322**, can be via any

security mechanism as long as the streaming server **325** and the custom URI handler **308** are both equipped with corresponding logic such as hardware firmware or software to implement this security. An example would be to use a secret, such as a codeword or other data that was pre-exchanged between the custom URI handler **308** and the streaming server **325**.

The video decoder **304**, video decryptor **306**, custom URI handler **308** and video player **310** can be implemented via one or more processing devices and one or more memory devices. Such processing devices can include a microprocessor, micro-controller, digital signal processor, microcomputer, central processing unit, field programmable gate array, programmable logic device, state machine, logic circuitry, analog circuitry, digital circuitry, and/or any device that manipulates signals (analog and/or digital) based on operational instructions that are stored in a memory. The memory can include a hard disc drive or other disc drive, read-only memory, random access memory, volatile memory, non-volatile memory, static memory, dynamic memory, flash memory, cache memory, and/or any device that stores digital information. Note that when the processing device implements one or more of its functions via a state machine, analog circuitry, digital circuitry, and/or logic circuitry, the memory storing the corresponding operational instructions may be embedded within, or external to, the circuitry comprising the state machine, analog circuitry, digital circuitry, and/or logic circuitry.

The network interface **302** can include a modem, transceiver or other network interface adaptor for coupling to the streaming server **325** either directly or indirectly via a serial or parallel connection such as an Ethernet connection, Universal Serial Bus (USB) connection, an Institute of Electrical and Electronics Engineers (IEEE) 1394 (Firewire) connection, small computer serial interface (SCSI), high definition media interface (HDMI) connection or other wired connection that operates in accordance with either a standard or custom interface protocol. In addition or in the alternative, the network interface **302** can include a wireless link for coupling to the streaming server **325** either directly or indirectly through one or more devices that operate in accordance with a wireless network protocol such as 802.11a,b,g,n (referred to generically as 802.11x), Bluetooth, Ultra Wideband (UWB), 3G wireless data connection, 4G wireless data connection or other wireless connection that operates in accordance with either a standard or custom interface protocol.

FIG. **12** presents a flowchart representation of a method in accordance with an embodiment of the present invention. In particular a method is shown for use in conjunction with one or more functions and features described in conjunction with FIGS. **1-10**. In step **400**, playlist data are stored corresponding to a plurality of video programs available from at least one video source, the playlist data including links to a plurality of segments for each of the plurality of video programs and a custom universal resource indicator (URI) for accessing at least one encryption key for decrypting at least one of the plurality of segments. Step **402** includes bidirectionally communicating, via a network interface, with a client device and at least one video source via at least one network. In step **404**, a program request for a selected one of the plurality of video programs is received from the at least one client device via the network interface. In step **406**, a custom key request is received via a custom URI handler of the client device and to access the at least one encryption key corresponding to at least one of the plurality of segments. In step **408**, secure key data is sent to the client device, in response to the custom key request, and in accordance with a custom key exchange protocol.

FIG. **13** presents a flowchart representation of a method in accordance with an embodiment of the present invention. In particular a method is shown for use in conjunction with one or more functions and features described in conjunction with FIGS. **1-10**. Step **410** includes bidirectionally communicating with a streaming server via a network interface and at least one network, wherein the streaming server stores playlist data corresponding to a plurality of video programs available from at least one video source, the playlist including links to a plurality of segments for each of the plurality of video programs and a custom universal resource indicator (URI) for accessing at least one encryption key for decrypting at least one of the plurality of segments. In step **412**, a program request is generated and sent to the streaming server for a selected one of the plurality of video programs via the network interface. In step **414** a custom key request is generated via a custom URI handler to access the at least one encryption key corresponding to at least one of the plurality of segments of the selected one of the plurality of video programs. In step **416** secure key data is received from the streaming server in response to the custom key request and in accordance with a custom key exchange protocol.

In preferred embodiments, optional circuit components can be implemented using 0.35 micron or smaller CMOS technology. Provided however that other circuit technologies, both integrated or non-integrated, may be used within the broad scope of the present invention.

As one of ordinary skill in the art will appreciate, the term "substantially" or "approximately", as may be used herein, provides an industry-accepted tolerance to its corresponding term and/or relativity between items. Such an industry-accepted tolerance ranges from less than one percent to twenty percent and corresponds to, but is not limited to, component values, integrated circuit process variations, temperature variations, rise and fall times, and/or thermal noise. Such relativity between items ranges from a difference of a few percent to magnitude differences. As one of ordinary skill in the art will further appreciate, the term "coupled", as may be used herein, includes direct coupling and indirect coupling via another component, element, circuit, or module where, for indirect coupling, the intervening component, element, circuit, or module does not modify the information of a signal but may adjust its current level, voltage level, and/or power level. As one of ordinary skill in the art will also appreciate, inferred coupling (i.e., where one element is coupled to another element by inference) includes direct and indirect coupling between two elements in the same manner as "coupled". As one of ordinary skill in the art will further appreciate, the term "compares favorably", as may be used herein, indicates that a comparison between two or more elements, items, signals, etc., provides a desired relationship. For example, when the desired relationship is that signal **1** has a greater magnitude than signal **2**, a favorable comparison may be achieved when the magnitude of signal **1** is greater than that of signal **2** or when the magnitude of signal **2** is less than that of signal **1**.

As the term module is used in the description of the various embodiments of the present invention, a module includes a functional block that is implemented in hardware, software, and/or firmware that performs one or module functions such as the processing of an input signal to produce an output signal. As used herein, a module may contain submodules that themselves are modules.

Thus, there has been described herein an apparatus and method, as well as several embodiments including a preferred embodiment, for implementing a media distribution system. While described primarily in terms of video programming, it is understood that the video programming can include associated audio and that the present invention could likewise to be applied to associated audio or the distribution of audio programming that is unassociated with video. Various embodiments of the present invention herein-described have features that distinguish the present invention from the prior art.

It will be apparent to those skilled in the art that the disclosed invention may be modified in numerous ways and may assume many embodiments other than the preferred forms specifically set out and described above. Accordingly, it is intended by the appended claims to cover all modifications of the invention which fall within the true spirit and scope of the invention.

What is claimed is:

1. A streaming server comprising:

a file system that stores playlist data corresponding to a plurality of video programs available from at least one video source, the playlist data including links to a plurality of segments for each of the plurality of video programs and a custom universal resource indicator (URI) for accessing at least one encryption key for decrypting at least one of the plurality of segments;

a network interface, coupled to bidirectionally communicate with a client device and to bidirectionally communicate with the at least one video source via at least one network;

a command handler, coupled to the network interface, that receives a program request for a selected one of the plurality of video programs from the client device via the network interface and further receives a custom key request via a custom URI handler of the client device and to access the at least one encryption key corresponding to at least one of the plurality of segments and in response to the custom key request, that sends secure key data to the client device in accordance with a custom key exchange protocol that is generated based on the at least one encryption key; and

an encryption key generator, coupled to the command handler, that generates the at least one encryption key on-demand in response to the custom key request and without the at least one encryption key being saved to a storage device of the streaming server.

2. The streaming server of claim **1** wherein the at least one encryption key includes a plurality of encryption keys each corresponding to one of the plurality of segments of the selected one of the plurality of video programs.

3. The streaming server of claim **1** wherein the at least one encryption key is generated to be substantially unique to the custom key request.

4. The streaming server of claim **1** wherein the command handler generates the secure key data by encrypting the at least one encryption key.

5. The streaming server of claim **1** wherein the file system is a virtual file system and the command handler operates by:

retrieving the selected one of the plurality of video program from the at least one video source via the network interface in response to the program request;

segmenting and encoding the selected one of the plurality of video programs into a plurality of encoded segments via a video encoder;

generating encrypted segments from the plurality of encoded segments, via a video encryptor, in accordance with the at least one encryption key; and

sending, via the network interface, a streaming video signal to the client device that includes the plurality of encrypted segments.

6. A client device comprising:

a network interface, coupled to bidirectionally communicate with a streaming server via at least one network, wherein the streaming server stores playlist data corresponding to a plurality of video programs available from at least one video source, the playlist data including links to a plurality of segments for each of the plurality of video programs and a custom universal resource indicator (URI) for accessing at least one encryption key for decrypting at least one of the plurality of segments;

a custom URI handler;

a video decoder;

a decryption device;

a video player, coupled to the network interface, the custom URI handler, the video decoder and the decryption device, that operates by:

generating a program request to the streaming server for a selected one of the plurality of video programs via the network interface and further generates a custom key request via the custom URI handler to access the at least one encryption key corresponding to at least one of the plurality of segments of the selected one of the plurality of video programs; and

receiving, in response to the custom key request, secure key data from the streaming server in accordance with a custom key exchange protocol, the secure key data indicating the at least one encryption key, and wherein the at least one encryption key is generated on-demand in response to the custom key request and without the at least one encryption key being saved to a storage device of the streaming server.

7. The client device of claim **6** wherein the at least one encryption key includes a plurality of encryption keys corresponding to the plurality of segments of the selected one of the plurality of video programs.

8. The client device of claim **6** wherein the customer URI handler is registered with an operating system of the client device and wherein the operating system identifies a format of the custom URI and invokes the custom URI handler in response to identifying the format of the custom URI.

9. The client device of claim **6** wherein the video player operates by decrypting the secure key data via the decryption device to generate the at least one encryption key.

10. The client device of claim **9** wherein the video player operates by decrypting the at least one of the plurality of segments, via the decryption device and the at least one encryption key, to generate at least one encoded segment.

11. The client device of claim **9** wherein the video player operates by decoding the at least one of the plurality of segments, via the video decoder, to generate at least one decoded segment.

12. A method for use in a streaming server, the method comprising:

storing playlist data corresponding to a plurality of video programs available from at least one video source, the playlist data including links to a plurality of segments for each of the plurality of video programs and a custom universal resource indicator (URI) for accessing at least one encryption key for decrypting at least one of the plurality of segments;

bidirectionally communicating, via a network interface, with a client device and at least one video source via at least one network;

receiving a program request for a selected one of the plurality of video programs from the client device via the network interface;

receiving a custom key request via a custom URI handler of the client device and to access the at least one encryption key corresponding to at least one of the plurality of segments;

generating the at least one encryption key on-demand in response to the custom key request and without the at least one encryption key being saved to a storage device of the streaming server;

generating secure key data indicating the at least one encryption key; and

sending, in response to the custom key request, the secure key data to the client device in accordance with a custom key exchange protocol.

13. A method for use in a client device, the method comprising:

bidirectionally communicating with a streaming server via a network interface and at least one network, wherein the streaming server stores playlist data corresponding to a plurality of video programs available from at least one video source, the playlist data including links to a plurality of segments for each of the plurality of video programs and a custom universal resource indicator (URI) for accessing at least one encryption key for decrypting at least one of the plurality of segments;

generating a program request to the streaming server for a selected one of the plurality of video programs via the network interface;

generating a custom key request via a custom URI handler to access the at least one encryption key corresponding to at least one of the plurality of segments of the selected one of the plurality of video programs; and

receiving, in response to the custom key request, secure key data from the streaming server in accordance with a custom key exchange protocol, the secure key data indicating the at least one encryption key, wherein the at least one encryption key is generated on-demand in response to the custom key request and without the at least one encryption key being saved to a storage of the streaming server.

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